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Procedia Engineering 44 (2012) 598 – 599

Procedia Engineering

www.elsevier.com/locate/procedia

Euromembrane Conference 2012

[OD33]

Progress of RO membrane technology based on scientific research for seawater and brackish water desalination

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RO membrane technologies have made great progress in last 50 years. In seawater and brackish water desalination field, both energy saving and water quality improvement have been two major subjects. Today, the energy consumption in RO membrane seawater desalination process becomes less than one tenth, compared to those of 1970's. NaCl rejection of RO membrane becomes more than 99.7%. However, advanced membranes are still demanded to achieve lower cost, lower energy consumption and higher water quality.

In order to obtain further excellent performance, Toray has been executing fundamental research for RO membranes on investigating physical and chemical properties through PALS(Positron annihilation lifetime spectroscopy) study, Computer chemistry and TEM (Transmission electron microscopy) analysis, which has resulted in the advanced RO membranes with high flux, high rejection, excellent chemical durability and so on. In this presentation, these results and job references will be discussed.

Pore size analyses for separating functional layer in composite SWRO membranes were conducted with PALS study, and membranes showed pore sizes in the range of 5.6 - 7.0 Å. It was considered that this range of pore in the separating functional layer would characterize the membrane property. Furthermore, the correlation between pore size of RO membrane and boron permeability was revealed. It was suggested that the pore size in separating functional layer was regarded as one of the major factors to control solute removal performance of RO membranes.

In addition, The molecular dynamics simulations, based on the chemical structures established by 13C NMR study and the estimated amount of water, were performed. In order to determine pore sizes in the polymer models, the Connolly surface calculations were performed to water-deleted optimized polymer models. The calculation results showed that the pore sizes were estimated as 6 - 8 Å, which were well agreed with those of measured from PALS analyses. The comparison between pore size of RO membrane and typical removal substances, such as boric acid and sodium ion, were conducted by calculation with considering their hydrated state. Sodium ion was strongly hydrated, however, boric acid was hardly hydrated in neutral pH region. Consequently, the pore size of RO membrane was almost same as a hydrated sodium ion, but was a little larger than a non-hydrated boric acid. It was considered that it's reason why permeability of boron is larger than that of NaCl. Only a little difference in the size between pore and substances, including the difference between hydrated states, must dominate the removal performance.

The structural analysis with TEM through a special treatment of membrane for preserving the structure gave precise image of cross section of protuberance, and it enabled a quantification of surface morphology.According to the precise image, since the inside of protuberance was proved as a cave-like structure, the contribution of this structure to water permeability was agreeable. With the comparison between membranes having different water permeability, larger membrane surface area or thinner membrane thickness showed higher water permeability. Consequently, the correlation between the morphology of protuberance and water permeability of membrane was revealed. Thus, the total structural study relating to the RO membrane performance of solute removal and water permeability has been greatly progressed by the pore size and the morphology analyses. In this presentation, new energy-saving and high rejection membranes utilizing these studies and its utility study will be introduced.

doi:10.1016/j.proeng.2012.08.497

Through the abovementioned studies, a special molecular design, which controls physical and chemical property of RO membranes, is found to be necessary to develop further renovative membranes. On the basis of this knowledge, Toray has developed new RO membrane elements with high solute rejection performance for SWRO processes. The lineup of RO membrane elements for SWRO processes is made. TM820A shows 93% of boron rejection rate with high TDS rejection rate. TM820C, TM820E and TM820S have both high boron rejection rate and high water productivity. TM720C is utilized for second stage in multi-stage process due to the tolerance of alkaline agent. And most recently, TM820R, which has achieved coexistence of high solute rejection rate and high water productivity, has been released. TM820R has already been run with high performance and stable operation. Additionally, extremely high rejection membrane TM820K and further energy-saving membrane TM820L are shown as new lineup products. Toray has developed new RO membrane elements with high solute rejection performance for BWRO process. The lineup of RO membrane elements for BWRO processes is made. TM720 shows high TDS rejection rate. TMG20 and TMH20 for energy saving can be operated under low pressure. TML20 shows eminent low fouling performance. TMD720D has superior chemical tolerance with both high TDS rejection rate and high water productivity.

Toray advanced BWRO membrane elements have been made in progress. In this presentation, new membranes with high water productivity, high solute rejection and high chemical durability utilizing fundamental studies will be introduced.

Keywords: Reverse osmosis, seawater desalination, brackish water desalination, chemical durability